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ABSTRACT

Because knowledge of the component subskills of causal reasoning would aid in planning elementary science curricula, this study sought to identify component abilities through the individual administration of a battery of 29 tests to a randomly-selected sample of 84 first-graders, evenly divided by sex. These tests were: (1) verbal tests of causality (3 variables), (2) hypothesized causal components (10 variables), (3) causal demonstrations (8 variables), (4) Piagetian concrete operational tasks (5 variables), (5) Piagetian formal operational tasks (2 variables), (6) intelligence (1 variable), and (7) descriptive measure (1 variable). The results were analyzed by submitting the 30 variables to a maximum-likelihood factor analysis with a varimax rotation. Through this process, a verbal causal reasoning factor, including the 5 component subskills of chance, skepticism, perspectives, completing "because" statements, and detecting incongruous causal relations, was identified. Other results fail to support both Piaget's theory that preoperational thought leads to precausal explanations and Piaget and Inhelder's theory of the unitary nature of logical thinking. Rather, results suggest that at least 3 relatively independent abilities are involved in logical thinking. (MH)

A FACTOR ANALYTIC STUDY OF CHILDREN'S CAUSAL REASONING[1]

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Paper presented at the annual meeting of the American Educational Research Association, Minneapolis, Minnesota, March 6, 1970.

[1] This study is based on the writer's doctoral thesis, Ontario Institute for Studies in Education, University of Toronto. The author is indebted to the members of his thesis committee, Carl Bereiter (Chairman), David Brison, Ellen Regan and Edmund Sullivan, and to Glen Evans for their assistance in completing the study.

INTRODUCTION

The types of causal explanations which children use are of major importance. This is true since naturalistic explanations characterized by spatial contact, mechanical contact, or logical deduction, will normally lead to a greater degree of prediction, control and understanding of events than nonnaturalistic explanations based on magic, animism, supernaturalism, or fantasy. Thus, the ability to learn and understand physical explanations of cause and effect is an integral aspect of science education at the preschool and elementary school level (Karplus, 1962). The literature on child causality, however, seems to provide few empirical findings or even tangible suggestions concerning what a teacher or programmer should or should not include when developing a science curriculum.

A potentially valuable contribution to the developing of science programs could be made by identifying some of the various intellectual abilities which contribute to children's causal reasoning. Such component abilities could serve subsequently, as specified objectives in the planning and sequencing of elementary science programs.

The present study was designed to identify a number of specific abilities which contribute to a child's understanding of naturalistic causal explanations. In addition, since Inhelder and Piaget's (1958) model of logical thinking is predicated on an underlying stage of precausality, the present study sought to investigate some of their theoretical formulations. Children in the stage of precausality, according to Piaget (1930), give predominantly nonnaturalistic explanations. First, this study attempted to investigate Piaget's (1953) contention that children who give precausal explanations do so because they are preoperational in their thinking. Second, this study attempted to determine whether children's causal explanations are related to their "logical operativity" in some of Inhelder and Piaget's (1958) problem solving situations.

PROCEDURE[1]

Subjects. The subjects consisted of 42 boys and 42 girls randomly selected from the four first-grade classes in the Cedar Brook Public School, Scarborough, Ontario. The age range of the sample was 6:3 to 7:5 — a total range of 14 months.

Instruments. A battery of 29 tests was assembled which included criterion measures of causal reasoning, tests of hypothesized causal components, various Piagetian tasks of both a concrete and formal operational nature, and an intelligence measure. All tests except the intelligence measures were unstandardized. These tests were as follows:

1. Verbal tests of causality (3 variables)

   (A) Causal explanations of familiar objects based on Nass (1956). Objects included are those which the child could have possibly but had not necessarily experienced directly — car, bicycle, etc. (B) Remote objects or those which the child could not have directly experienced — clouds, stars, moon, etc. (Nass, 1956). (C) Questions requiring causal explanations of malfunctions, e.g., ships sinking. All explanations were classified according to three categories — physical, nonnaturalistic, and "I don't know". The criteria for the first two categories were developed by Nass (1956) and have proved to be highly reliable (Elitcher, 1967; Nass, 1956). All phenomenistic explanations were considered as being nonnaturalistic. The last category — "I don't know"—included shoulder shruggs and statements by the Ss that they did not know. Causal reasoning scores (henceforth called CR scores) were computed by assigning two points for each physical explanation, one point for each "I don't know," and zero points for each nonnaturalistic explanation within a given category.

2. Hypothesized causal components (10 variables)

   Ten possible component abilities of causal reasoning were hypothesized. These included:

[1] A complete description of the instruments, test and rater reliabilities, and procedures is given in Berzonsky (1969).

Component	Task
1. Understand chance events	Refrain from assigning causal significance to a chance coincidence of events.
2. Perspectives	Alter perspective or point of view when making a judgment.
3. Relational judgment	Understanding the relative status of such terms as right-left or above-below.
4. Verbal Seriation	Seriate three relations mentally.
5. Verification	Check or verify an answer before responding.
6. Detecting Incongruities	Detect contradictions in causal explanations presented verbally.
7. Sentence Completion	Complete causal statements in a syntatically correct manner.
(a) "because"	Relate effects to causes, e.g., "The tree fell down because . . ."
(b) "and so"	Relate causes to effects, e.g., "Mother ran out of sugar and so . . ."
(c) discordance	Produce an exception to a given law, e.g., "Jane dropped the jar but . . ."
8. Skepticism	Understand that no one, including the child himself knows all the answers, e.g., "Does your teacher ever make mistakes?"

3. Causal Demonstrations (8 variables)

Two tasks (teeter totter and raising the water level in a container) were used. The child was asked to predict what would happen and, after a demonstration, to explain the phenomenon. The tasks were administered under two conditions — standard and extinction. Under the extinction conditions results contrary to what one could normally expect occurred. For example a lead weight was surreptitiously placed under the side of the teeter-totter with one block thus causing the side with two blocks to go up instead of down. Explanation scores were based on the same criteria as those used for the verbal tests (cf. above), and prediction scores under both conditions were calculated.

4. Piagetian Concrete Operational Tasks (5 variables)

(A) Two class inclusion tasks — wooden beads and animals — based on Piaget (1950). (B) Two conservation tasks dealing with plasticine in which two transformations occur, and liquid which required S to actually pour "just as much" liquid into a tall-and-thin glass as E had poured into a short-and-fat glass. This latter task according to Piaget (1966) exemplifies "true conservation" since the child must use compensation-based reasoning rather than merely rely on an identity-based concept. (C) A seriation task adapted from Elkind (1964).

5. Piagetian Formal Operational Tasks (2 variables)

Two tasks adapted from Inhelder and Piaget (1958) were included as measures of the Ss' logical abilities in actively solving problems. They were the chemical combinations problem and oscillations of a pendulum. Both tasks were scaled.

6. Intelligence (1 variable)

Raw score total on the Dominion Group Test of Learning Capacity -- Primary.

7. Descriptive Measure (1 variable)

Age in months.

Testing Procedure. The aforementioned battery of tests, except for the intelligence test, was administered individually by the author. The items from the verbal tests of causality were randomly mixed together and always administered first. The three main sets of tasks (A. Causal Demonstrations B. Concrete Operational and C. Formal Operational) were administered in a counterbalanced order according to sex. Items within these main sets were also counterbalanced according to sex. Items from the sentence completion tests and the other causal components tests were randomly mixed and administered in subsets between the various main sets of tasks. Administration of the entire battery required approximately 95 minutes and was completed in two sessions, morning and afternoon, during the same day.

RESULTS

The data were analyzed by submitting the intercorrelation matrix of the 30 variables to Joreskog's (1966) maximum-likelihood method of factor analysis. The analysis indicated that five factors best fit the data. This estimate is based on the smallest number of factors that yielded a nonsignificant X^2 value at the .05 level (Harman, 1968). These factors were rotated to the varimax criterion. The results of the factor analysis are presented in Table 1.

Insert Table 1 about here

Causal Reasoning: Factor I was identified as a causal reasoning factor. Three of the twelve variables with loadings of .30 or greater, were criterion tests of causal reasoning and two of these had the highest loadings. Five of the hypothesized causal components and the intelligence measure also loaded on this factor.

Operational Thought. All five tasks that are said by Piaget to require concrete operational thinking for solving them have significant loadings on Factor II. The perspectives, mental seriation and discordance variables, likewise seem to require a type of mental agility or ability to "decenter," which is at least analogous to the mental reversibility characteristic of operational thinking. Consequently, Factor II is identified as concrete operational thought.

Problem Solving. The significant loadings of the two problem solving tasks and the verification test appear to define Factor III as some type of problem solving ability. Some aspects of intelligence also seem to be related. The loading of skepticism seems to suggest some type of "wait and see" attitude that is part of solving problems and which, most likely, is also reflected to some extent in an intelligence test.

Causal Explaining in Concrete Situations. Five of the seven variables that load above .30 on Factor IV involve the causal demonstration tasks and all four explanation conditions are represented. Thus Factor IV suggests some type of causal explaining ability when the event itself is present and readily observable.

Understanding the Concept of "Force". Factor V appears to involve an understanding of forces. Comprehending the relative effect of the force exerted by objects on a teeter-totter balance seems to be necessary for successful performance on the two teeter-totter variables that have significant loadings on this factor. The fact that both of these variables also load on Factor IV (causal explaining in concrete situations) suggests that causal reasoning ability does not account for these loadings. The malfunctions variable, which loads on Factor V, while presented in a different mode, again seems to entail an understanding of "forces" that puncture tires, sink ships, make holes in roofs, and so forth.

DISCUSSION

The significant loadings of the five hypothesized component abilities on the Causal Reasoning Factor lends credibility to the contention that they are related to the ability to reason causally in a naturalistic manner. The highest loading of the component abilities on this factor was contributed by the "understanding chance events" variable. The significant loading of the "incongruities" component suggests that a child who gives nonnaturalistic causal explanations also tends to be unable to detect contradictions in causal explanations presented to him verbally. The significant loading of the "because" subtest indicates that the ability to complete or construct a statement of cause and effect in a syntactically proper manner is a related aspect of causal reasoning. Likewise, the loading of the "perspectives" variable on Factor I suggests that the understanding of cause and effect is related to the appreciation of and ability to coordinate various points of view. Finally, it appears that children who are "skeptical" of adult infallibility are less apt to give nonnaturalistic explanations than their less "skeptical" counterparts. Accordingly it could be suggested that perhaps such skeptical children may be more prone to actively search and seek out explanations once they admit that they do not know all the answers.

The five hypothesized components that failed to load on the Causal Reasoning Factor deserve some comment. These variables included the "relational" and "verbal seriation" components and two conjunctions, "and so" and "discordance". It may be suggested that these components are at a higher developmental level than the elementary ability being examined. In other words, while these components bear little relationship to the giving of types of causal explanations (physical vs. nonnaturalistic) they may be quite necessary when the scientific correctness of these physical explanations are examined. The near zero loading of the verification component on this factor may be related to the fact that the verbal causal reasoning items offer no recourse to verification. That is, no opportunity is provided for the child to check his answer before responding.

The high loadings on Factor II of the various tasks which purportedly require the use of concrete operations to solve and understand, offer considerable support for Piaget's (1950, 1953) views on the unity of operational thought. An examination of the testing procedures employed in administering these tasks offers little support for an alternate hypothesis that this clustering is due to similarities in test formats.

The possibility that this finding is due to bias in the selection of instruments must be considered. When the test battery was being chosen care was taken to select the "best" indicators of operational thought. Hence, the tasks included were what Piaget (1950), after decades of study, has found to be the best indicator of operational thought (conservation) and two of the major "groupings" of the operational plane of thought (class inclusion and seriation). It is possible that through the years some type of empirical selection similar in nature to that used in selecting intelligence items for a particular age level occurred. Thus, what holds these items together empirically may not be some underlying qualitative structure but rather a multiplicity of developmentally concurrent factors. Some support for this interpretation may be found in the loading of the intelligence measure on Factor II.

These findings are consistent with the findings of Stephens *et al.* (1969) in another factorial study of Piagetian operational thought. Yet the wide age range of their sample may have accentuated the inter-task consistency which they found. The present findings, however, are at variance with those reported by O'Bryan and MacArthur (1967, 1969) in factorial studies of various Piagetian tasks said to be indicative of concrete operations. The fact that the present study included the main tasks which have, time and again, been found by Piaget to correlate together may account for this divergence. Inclusion of other tasks in the test battery that have received less attention by Piaget yet are still said to be indicative of concrete operational thought might have yielded a similar breakdown of operational thought into discrete subfactors.

The problem solving factor that emerged from the analysis offers some support for the inter-item consistency of Inhelder and Piaget's (1958) problem solving tasks. Both problem solving tasks — chemical combinations and the oscillations of a pendulum — had significant loadings on Factor III. However, the exceedingly high loading of the verification test and the significant loadings of the skepticism and intelligence measures suggest that specific abilities and attitudes may be more important for this type of problem solving than any underlying logical factor. Likewise, the relative independence of causal reasoning (in either mode) and operational thought from this ability offers little evidence for the logical factor which is said to underlie these various abilities.

CONCLUSIONS

The major implications of these results have to do with the constructing of preschool and elementary science programs. The results suggest a number of component abilities of causal explaining which should serve as objectives in the development of a science curriculum. Likewise, when active problem solving is the point of focus, the results intimate that children should be taught how to verify their judgments. For both the enhancement of naturalistic causal explaining and problem solving, it appears that an instructional atmosphere, designed to promote an attitude of skepticism in the youngsters would be appropriate.

These findings also have implications for Inhelder and Piaget's (1958) model of logical thinking. First, the results fail to support Piaget's (1953) claim that children who give nonnaturalistic or precausal explanations do so because they are preoperational in their thinking. While both abilities were identified they bear little relationship to one another. Second, the results are at variance with the unitary nature of logical thinking postulated by Inhelder and Piaget (1958). Rather, at least three relatively independent abilities appear to be involved. Moreover, the high loadings of the component abilities on the causal reasoning and problem solving factors, suggest that the various skills and attitudes which children possess are more important than "structural" variations in their operational planes of thought.

TABLE I

Varimax Rotation of Factor Pattern

Variable[1]	Factors[2] I	II	III	IV	V
Raw Score IQ	.48	.39	.31		
CA - Months	.40				
CQ - Familiar	.56				
CQ - Remote	.66				
CQ - Malfunction					.40
Chance	.50				
Verbal Seriation		.38			
Perspectives	.30	.31			
Absolutes					
Verification			.99		
Incongruities	.42				
CC - because	.37				
CC - and so					
CC - discordance		.36		.31	
Skepticism	.36	.36	.32		
TT - Pre Score				.34	.50
TT- Resist. Ext.					
TT - Pre Expl.				.35	.93
TT - Ext Expl				.53	
WL - Pre Score					
WL - Resist. Ext.					
WL - Pre Expl	.31			.52	
WL - Ext Expl				.70	
CI - Beads		.90			
CI - Animals		.82			
Seriation	.41	.36		.46	
Cons Clay		.38			
Cons - Liquid		.53			
Chemicals	.37		.43		
Pendulum			.32		

[1] The following abbreviations are used:

CA - Chronological Age
CC - Causal Conjunctions
CI - Class Inclusion
CQ - Causal Questions
Cons- Conservation
Expl - Explanation
Ext - Extinction
TT - Teeter totter
WL - Water Level Apparatus

[2] Coefficients below .30 omitted.

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